Bauxite in the Morales-Cajibio area, Cauca, Colombia

H. ROSAS G.

The Morales-Cajobio area covers a 300 km² quadrangle located north of Popayán, Cauca, and is a part of a larger bauxite-bearing region extending to both flanks of the upper Cauca Valley.

The underlying rocks, representing the Popayán Formation, consist of Plio-Pleistocene clastic and pyroclastic deposits composed mainly of andesite fragments.

The bauxitic material occurs as discontinuous blanketlike deposits which were derivated from weathering of the Popayán Formation. The deposits appear to have formed preferentially on areas of gentle topography, and are conformable with the present weathering surface. Topographic and climatic conditions do not seem to have undergone substantial changes since the beginning of laterization. The material composing the deposits is a yellow-brown, soft, somewhat plastic clay with abundant gibbsitic aggregates, and is considered to represent an early stage of bauxitization. From this bauxitic clay high grade bauxite can be obtained by washing and screening.

Detailed maps showing the boundaries of deposits were made on the basis of drilling and geomorphologic interpretation. From these maps 80,000,000 metric tons of bauxitic clay are estimated to be present, which can yield 20,000,000 metric tons of high grade bauxite.

1. INTRODUCTION

Bauxite in the Morales-Cajibío area was first reported by R. Ordóñez (1968). In 1970, the Instituto Nacional de Investigaciones Geológico-Mineras initiated more detailed studies on bauxite in the upper Cauca Valley, a part of which is the Morales-Cajibío area. In the developing of these studies, a preliminary report dealing with the physical, mineralogical and chemical characteristics of the deposits was published by H. Rosas (1971). J. B. Cathcart (1972) made a description of the deposits and presented some qualitative X-ray and semiquantitative spectroscopic data.

The present report is based in part on writer's previous work and mostly upon more recent data obtained in the field and laboratory.

2. GEOLOGY

The rocks exposed in the Morales-Cajibío area represent the Popayán Formation, of Plio-Pleistocene age. This formation consists of conglomerates, agglomerates, volcanic tuffs and some lava flows, which were deposited in a fluvial-lacustrine basin between the Central and Western Cordilleras. The Popayán rests unconformable on rocks ranging between Paleozoic to Eocene. Because of the irregularities of the topographic surface on which this formation was deposited, its thickness varies from less than 1 meter to more than 500 meters.

Two members have been recognized within the Popayán Formation: 1) A lower member, up to 300 meters thick, composed of conglomerates and agglomerates alternating with tuffs and lava flows. This member crops out in the eastern marginal zones of the basin, and it appears affected by a slight tectonism, suggesting a Pliocene age. 2) An upper member, lacking lava flows and entirely clastic. It is lithologicaly similar to the lower member, and consists of conglomerates, agglomerates and tuffaceous beds. The member crops cut in the central part of the basin. The layers appear to be substantially horizontal and almost undisturbed. A Pleistocene age has been assigned to this member.

In the Morales-Cajibío area, only the upper member of the Popayán Formation is exposed. It forms a sequence of essentially horizontal layers of coarse conglomerates, agglomerates and some tuffaceous beds. More than 90 percent of the fragments composing the conglomerates and agglomerates are andesitic in composition. Fragments of diabase, schist and quartzite are also present. The fragments range in size from small pebbles to blocks more than 1 meter in diameter. With the exception of the tuffaceous beds, the layers are very irregular, and most are lenshaped. In some places the planes of stratification are imperceptible.

The clastic material composing the Popayán Formation was derived mostly from andesitic rocks of later Tertiary age, which make up a large part of the Central Cordillera to the east of the map area. The tuffs and lava flows were produced by intermittent eruptions of the Puracé and Sotará volcanoes, which are dormant at present.

The rocks composing the Popayán Formation are the parent material of the bauxite deposits concerned with this report. The aluminous composition of these rocks, the clastic condition, the small amount of cementing material and the consequent good permeability have offered favorable lithologic conditions for chemical weathering and bauxitization.

3. DESCRIPTION OF BAUXITE DEPOSITS

The deposits form a horizon of bauxitic clay (1), ranging from a few centimeters to 3 meters thick, and is located between the surface and 3 meters depth. The horizon corresponds approximately to the B horizon as used in pedology (Millar, Turk and Foth, 1966, p. 6).

The bauxitic clay is formed of two textural fractions: 1) A yellow-brown somewhat plastic clay, composed essentially of halloysite, iron oxides and minor amounts of amorphous aluminum hydroxide; and 2) cream colored, relatively hard concretionary bauxite aggregates, ranging in size from less than 1 millimeter to a few centimeters in length, and are composed of gibbsite crystals, cliachite (2), and a few impurities. Studies of bauxite aggregates in thin section indicate that aging causes crystallization of cliachite into gibbsite.

(1) The term "bauxitic clay" refers to the grade D of the modified Thoenen-Burchard classification of bauxite (Cloud, 1967, p. 25-26), which is defined as material containing between 30 percent and 45 percent alumina and less silica than alumina.

(2) Cliachite. Aluminum oxide, commonly present in bauxite, consisting of a "more or less amorphous-looking generally brownish material". (Goldman, 1955, p. 590) Goldman's definition of the term appears in the "Glossary of Geology" (1966, p. 12 sup.). A similar meaning was assigned to this term when it was considered as a synonimous of alumogel. (Clockman and Ramdohr, 1961, p. 455), Kerr (1959, p. 126, 206) described cliachite as a pisolitic or massive micro-amorphous material without any indication of crystalline structure under the polarizing microscopy. He makes clear that "The term microamorphous is used because X-rays studies have shown these materials to have directional properties sensitive to short wavelengths". In the report, the term cliachite refers to a material that shows in thin section the properties of cliachite, as described by Kerr.

Dehydration of bauxitic clay causes further overgrowth of the bauxite aggregates by agglomeration of dispersed aluminum hydroxide particles from the clay fraction. As a general rule, if dehydration takes place on relatively small amounts of bauxitic clay, after being removed from the ground, the bauxite aggregates are smaller than those formed by natural dehydration on the surface of outcrops. In the first case, the aggregates rarely grow more than 5 centimeters in length, while in outcrops they may be larger than 20 centimeters. The reason for this is that growing of aggregates in outcrops is augmented by an extra contribution of aluminum hydroxide particles carried in percolating waters from the interior of the soil to the surface. Surficial enrichement is usually accentuated when impurities are washed out by rain water. In this case, the bauxite aggregates become more conspicuous, and is why, that at first glance, it may appear that they are present only on the surface.

A continuous profile of the weathering zone shows the following horizons: 1) Organic soil. Black at the top and dark brown at the bottom. Average thickness 0.5 meters. 2) Yellow-brown clay. Earthy texture. Nonbauxitic material. Average thickness 1 meter. 3) Bauxite horizon (described above). Average thickness 2 meters. 4) Halloysitic clay. Light cream color. Very commonly the material preserves the texture of the individual source-rock fragments. Direct alteration of halloysitic clay seems to result in the formation of bauxitic clay. Average thickness 0.5 meters. 5) Zone of disintegration and decomposition of the source rock. Clayey at the top, grading downward to fresh rock. Shades of red and yellow. Average thickness 8 meters. 6) Source rock — Popayán Formation.

4. CHEMICAL ANALYSES OF BAUXITE

In table I, an analysis of bauxite aggregates is shown together with the average range in composition of the bauxitic clay.

TABLE I

Composition of bauxite aggregates and bauxitic clay from the Morales-Cajibio area, Cauca, Colombia (All values in percent)

Compound	*Bauxite aggregates*	*Bauxitic clay*
Al_2O_3	59.02	35.70-43.87
SiO_2	3.02	20.07-32.34
Fe_2O_3	4.43	10.16-13.03
TiO_2	1.19	0.74- 1.11
CaO	0.05	0.03- 0.08
MgO	0.12	0.24- 0.71
MnO	0.02	0.04- 0.10
Ignition loss	32.15	16.67-23.41

Analyses by J. Rodríguez, Instituto Nacional de Investigaciones Geológico-Mineras.

5. ORIGIN OF DEPOSITS

Initially the Popayán Formation formed a plateau that was gradually dissected by erosion. On this dissected plateau, bauxite deposits have been formed by chemical weathering.

The mineral and chemical characteristics of the deposits indicate that they are in an early stage of bauxitization. A part of the aluminum oxide occurs in amorphous form which has been considered to be the first stage in the bauxitization process and in the formation of the bauxite minerals, gibbsite, bohemite and diaspore (Frederickson, 1952, p. 3; Milligan and McAtee, 1952, p. 98).

The small depth at which the deposits occur, and the high degree of concordance with the modern soil profile (see description of deposits), not only corroborates the recent age of bauxitization but also suggests that the deposits are still forming. In fact, the present climatic conditions (1) conform to the requirements considered necessary for the formation of bauxite by weathering. That is, a warm climate of normal to abundant rainfall alternating with dry periods (Harder, 1952, p. 35).

Mohr (1933, p. 15) explains the effect of temperature on tropical soils by the relationship between macroflora, which builds humus, and the microflora which destroys it. Mohr believes that 25 °C is the critical temperature above which humus is destroyed faster than it is formed. Mohr (1933, p. 17, 18) also considers that the silicic acid of minerals is more soluble in pure waters than in humus-bearing waters. On the other hand, aluminum oxide is insoluble in pure water but is soluble in the presence of humus. On the basis of the above considerations, formation of bauxite by weathering has been considered to require a climatic environment in which the temperature probably exceeds 25 °C for most of the year. (Gordon and Tracey, 1958, p. 145).

The presence of humus in the modern soils of the Morales-Cajibío area below 25°, agrees with Mohr's considerations. However, bauxitization of these soils suggests that the presence of humus in tropical soils does not necessarily prevent the formation of bauxite.

Because of the modern age of the deposits, they appear genetically related to the present topography. The occurrence of bauxitic clay is restricted to the summits and more gentle flanks of smooth topographic ridges, and is generally absent in the bottom of the valleys. Almost no bauxite is present on slopes greater than 20°. Slopes dipping between 5° and 10° seem to offer a more favorable environment for bauxitization, since the bauxite horizon tends to be thicker on them.

6. MAPPING

Deposit maps were made on the basis of data obtained directly from outcrops, pits cuts, and drill holes; and on photo interpretation of two main geomorphologic features : 1) The present land forms are closely related to form, size and thickness of deposits (see Origin of deposits). 2) Bauxitic zones are slightly more resistant to erosion than barren zones. On account of this, bauxitic zones appear to be, on aerial photographs, somewhat more prominent than non-bauxitic ones, and commonly show smoother surfaces than the barren zones.

Maps included in this report are: 1) A nondetailed map (fig. 1) showing the distribution of bauxite in the entire Morales-Cajibío area. Since the discontinuous bauxite horizon underlies only parts of the land area, map units of 10, 20, 25, 30 and 35 percent have been differentiated on the basis of percentage of area underlain by bauxite. 2) A detailed map of 12 km² (Fig. 2) showing boundaries of individual deposits.

(1) The climate in the region is a humid tropical type, rainy most of the year, with some relatively dry periods. The record of precipitation, covering 27 years shows that the annual precipitation is 2,000 millimeters with 200 days of rain per year. Rainfull averages for the wettest and driest months, July and November respectively, were 50 millimeters and 320 millimeters. (Inst. Geogr. A. Codazzi, 1969, p. 67, 68, 69, 73). The average temperature in the area ranges between 19° and 21 °C.

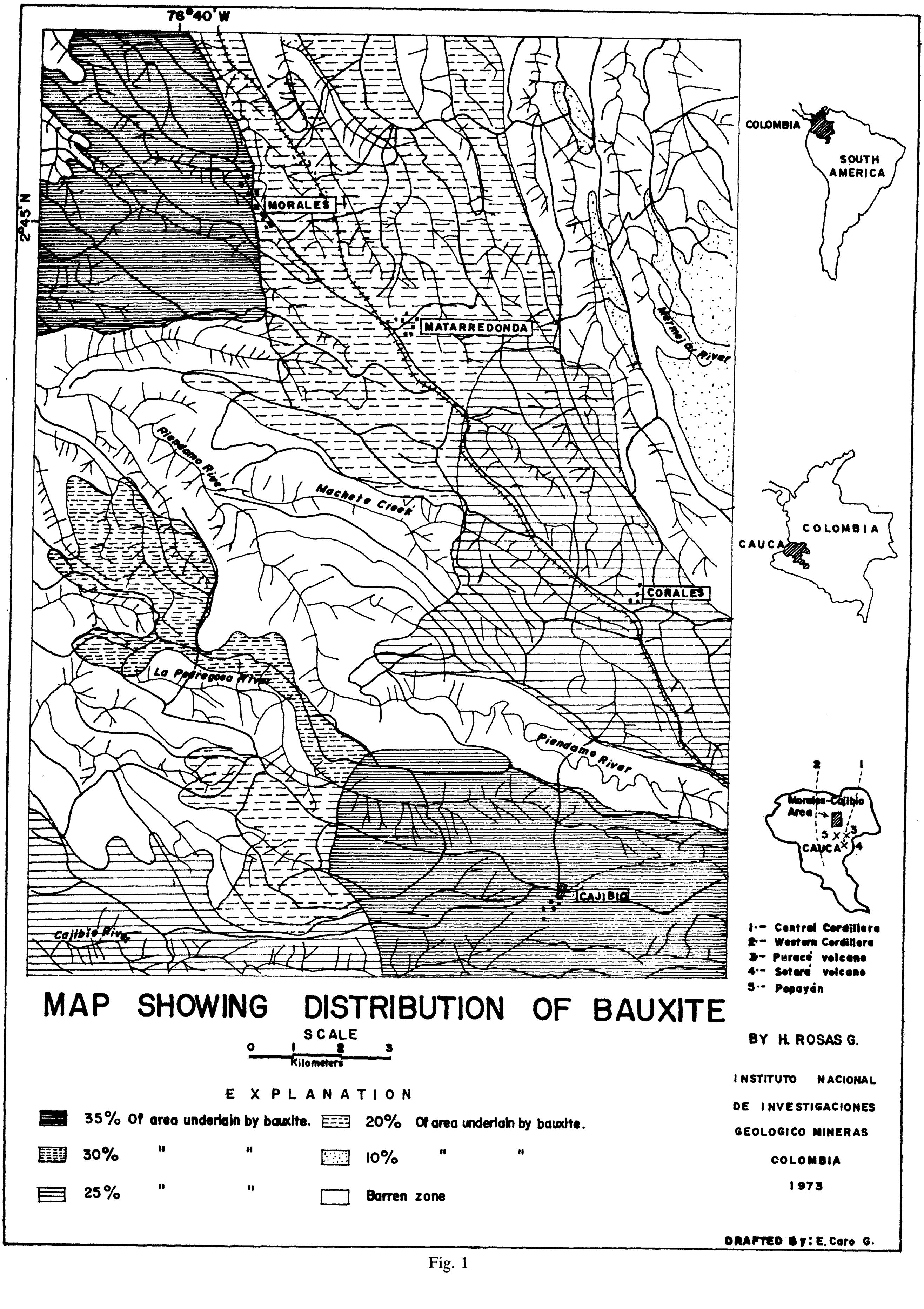
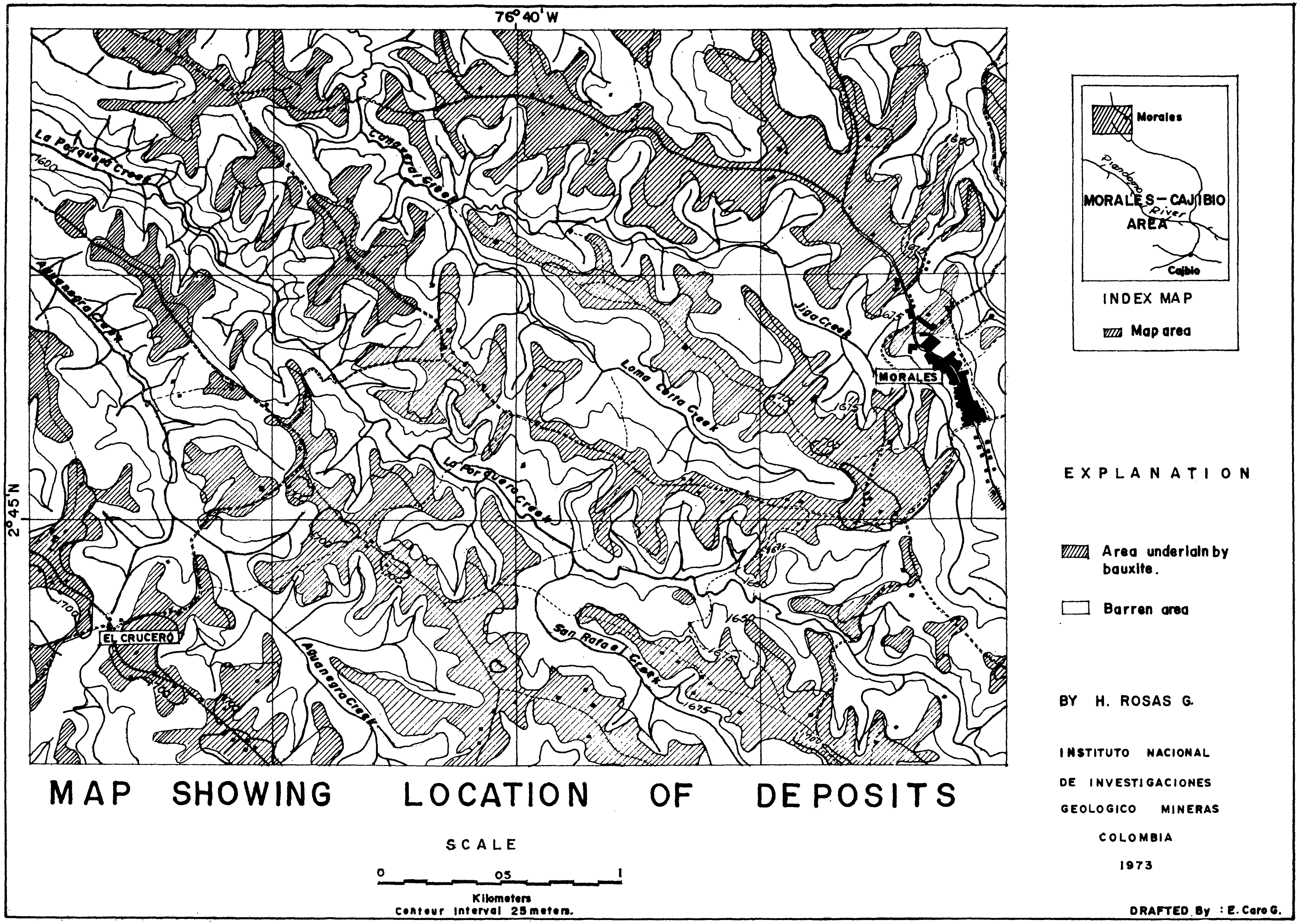

76°40'W
2°45'N
MORALES
MATARREDONDA
CORALES
CAJIBIO
Piendamo River
Machete Creek
La Pedregosa River
Cajibio River
COLOMBIA
SOUTH AMERICA
COLOMBIA
CAUCA
Morales-Cajibio Area
CAUCA
1.- Central Cordillera
2.- Western Cordillera
3.- Puracé volcano
4.- Sotará volcano
5.- Popayán
MAP SHOWING DISTRIBUTION OF BAUXITE
SCALE
0 1 2 3
Kilometers
E X P L A N A T I O N
35% Of area underlain by bauxite.
30% " "
25% " "
20% Of area underlain by bauxite.
10% " "
Barren zone
BY H. ROSAS G.
INSTITUTO NACIONAL
DE INVESTIGACIONES
GEOLOGICO MINERAS
COLOMBIA
1973
DRAFTED By: E. Caro G.

Fig. 1


76° 40' W
2° 45' N
La Porquera Creek
Aguanegra Creek
Loma Corta Creek
Jiga Creek
MORALES
EL CRUCERO
San Rafael Creek
MAP SHOWING LOCATION OF DEPOSITS
SCALE
0
05
1
Kilometers
Contour interval 25 meters.
Morales
MORALES - CAJIBIO AREA
Cajibio
INDEX MAP
Map area
EXPLANATION
Area underlain by bauxite.
Barren area
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GEOLOGICO MINERAS
COLOMBIA
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Fig. 2

7. BENEFICIATION

Some beneficiation tests have been made on the bauxitic clay. The material responds favorably to wet screening since the coarser bauxite aggregates are retained in the screen while the iron-clay fraction and finer bauxite aggregates are removed.

Loss of natural moisture of the bauxitic clay causes two opposite effects in beneficiation by wet screening: On the one hand, it promotes overgrowth of bauxite aggregates, allowing the recovering of coarser aggregates; and, on the other, facilitates the accretion of iron oxide particles into coarser masses, thus not allowing the removal of the finer bauxite aggregates.

Beneficiation tests have showed that, although coarser bauxite aggregates can be recovered from dried bauxitic clay, a larger proportion is obtained from the undried material. By screening (with water) it is found that aggregates coarser than 10 mesh, representing about 15 percent (by weight) of the whole material, can be recovered from previously dry bauxitic clay. Finer aggregates can not be recovered since they are as coarse as the iron oxide masses. From undried bauxitic clay, it is possible to recover aggregates coarser than 30 mesh, representing about 25 percent (by weight) of the whole material. Percentages were calculated on a dry basis.

8. RESERVES

The estimate of bauxite reserves in the Morales-Cajibío area is based on the following information: 1) Area of bauxite-bearing zones — graphically obtained from map (Fig. 1). 2) Percentage of zone underlain by bauxitic clay — from map (Fig. 1). 3) Thickness of bauxite horizon — average thickness 2 meters — field studies. 4) Specific gravity — 1.5 gr./cm^3.

From these data, a reserve of 80,000,000 metric tons of bauxitic clay (low grade bauxite) has been estimated to be present. As 25 percent of this tonnage can be obtained in the form of bauxite aggregates (high grade bauxite) by wet screening, the estimated reserves of high grade bauxite are 20,000,000 metric tones.

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Instituto Nacional de Investigaciones Geologíco-Mineras
Carrera 9/5-62, Popayán, Cauca (Colombie)